# QR codes in Engineering Laboratories – Improving Student Safety Engagement

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## Abstract

Engineering is a practical discipline and laboratory work is a fundamental necessity of engineering curricula and majority of engineering modules run by universities have significant elements of practical work embedded in them (Feisel et al 2005 and Rathod et al, 2016). It provides an active learning avenue that provides students with hands-on experience to support and strengthen in-lecture learning by enhancing the student's understanding of theoretical concepts (Nikolic, 2015). Laboratory safety is an important and continuous focus within academic institutions where a lack or lapse could sometime lead to serious or even fatal consequences. Using Quick Response Codes (QR Codes), students can access, on-demand, the necessary training and safety instructions for them to use specialised engineering equipment and/or carry out specially designed procedures, imbuing them with specific knowledge to execute laboratory activities confidently and securely. Mobile devices in teaching have been a topical issue and the use of QR codes aims to create an independent learner through the engagement using personal technology like smartphones and tablets with the intention of improve the level of engagement during active laboratory activities by using a medium that the students are au fait with. This paper outlines the delivery method used in the implementation of QR codes within 1st year engineering laboratories to aid basic safety training for engineering practical activities. It also discusses the potential use of QR codes in engineering laboratories to deliver on-demand information and capture training needs at the time and location that is required.

## Introduction to Laboratories in Engineering Education

Engineering is a practice-based subject where doing is key. Laboratories are used through all levels and disciplines in engineering education as a way to demonstrate basic information and gain hands on practical skills to compound their understanding of theoretical concepts and implement application-based practice (Sedghpour et al, 2013)

The ability to successfully accomplish a practical task is an important professional skill requirement, designated by The Engineering Council (2014) as a key competency required of an engineer. The engineering profession requires manipulation of resources for the benefit of humankind. To accomplish this, engineers must have knowledge that goes beyond theory, a knowledge that is normally achieved in hands-on, practical laboratories.

Laboratories are hence an indispensable aspect of developing these disciplinary, practical skills required, e.g., from learning to use modern engineering tools and equipment to the ability to conduct experiments, and one of the core elements of these skills includes the ability to conduct the task and themselves in a safe and effective manner. Being a practical profession, labs also support and develop their self-identity as an engineer (Edward, 2002). Student satisfaction must be at the core of any laboratory experience and Nikolic (2015) has demonstrated that resources that provides details on how to satisfactorily conduct a task have yielded the highest satisfaction scores.

Types of engineering practical are dependent on specific engineering disciplines with different emphasis on the type of core knowledge and skillset required, for example, an electronics student might need to be familiar working with soldering irons while a mechanical student would need to be handy with mechanical hand tools. However, the hands-on aspect of practical work often has significant safety related risk associated with it, which must be prioritised and addressed accordingly in order to provide an immersive experience for the student to learn in a safety environment (Shariff et al, 2012). The practical aspect of health and safety is critical in engineering and there is an identified need to ensure that students leaving university are equipped with the knowledge and principles of safe working (EU-OSHA, 2010).

## Safety in Engineering Activities

Accidents in laboratory setting are a concern for universities (Ismail et al, 2015). A typical engineering laboratory setting, for example, contains multiple hazards - acids and chemicals, hazardous equipment, pressurised gas, poisonous fumes etc. There is hence a concern that students often face a variety of risks and threats whilst working and participating in laboratory activities. Whilst we acknowledge that serious accidents in academic laboratory environments are fortunately rare in the UK, they are by no means uncommon. Ensuring the safety of students under our care is not only our legal obligation but also a moral one. By providing the necessary training and education to work to prevent harm in practical activities, we are thereby helping the student to fully benefits from the hands-on learning activities.

Accidents in labs can be the result of many factors, with the lack of appropriate knowledge and attitudes toward safety and unsafe personal practices being pertinent factors that are beyond the control boundaries of supervising staff or control measures put in place (Abdullah and Aziz, 2020).

## QR Codes for Safety Learning

Engagement with learning using mobile devices is exciting for students (Lynch, 2015). Students tend to respond more positively to the stimulus when using mobile devices and they tend to stay focus on the task thereby enabling them to self-correct as they proceed

(Lynch, 2015). Mobile devices also provide students with the opportunity to engage with the activity outside the lab and possibilities to prepare prior to sessions. Personal technology is an “anywhere, anytime” learning tool to support the development of self-regulated learners, encouraging independent learning through engagement (Mueller 2011). Kolb (2008) discussed a ‘disconnection’ between how students learn outside of school and how they learn in the classroom, and as faculty, we have little appreciation for the skills that students use outside of the classroom. We tend to think of devices such as cell phones as “toys” and see these technologies as distracting and even harmful. Kolb (2008) urges the recognition that smart mobile devices can be a powerful tool for education and to find ways to integrate them into the classroom. With the changing educational landscape, it is important to recognise that students learn in many ways and therefore the delivery of educational content should adapt accordingly. Joordens et al. (2012) have reported that most students show a higher level of willingness to learn when technology enabled learning practices are employed.

QR (Quick Response) codes, small matrix like codes, can be readily accessed, usually with an app, using most smartphones or smart devices that have integrated cameras. QR codes are also easy to generate, implement and manage. Information can be updated at point source hence reducing the need for changing the information individually. QR codes provide immediate valuable and relevant information to the user at the point of contact and are highly trackable. Users are able to scan these codes and get access to the timely, knowledge and information at the specific location, for a specific lab equipment or at the point of need (Walsh, 2010). QR codes are used to provide a link to content found on the Internet, are increasingly seen in many places, with point of need information successfully employed in libraries and museums (Ashford, 2010, Pulliam et al, 2010 and Shultz, 2013) and it is this point of need information that is highly relevant to what this project is aims to achieve.

This project aims to engage engineering students through bespoke safety, instructional materials using embedded in QR codes during active learning practical sessions. Training will then be achieved through the incorporation of self-directed, user-focussed instructional materials with relevant information for equipment, instrument and technical procedures. This paper sets out the delivery method used in the implementation of QR codes within 1st year engineering laboratories to aid basic safety training for engineering practical activities. It also discusses the potential use of QR codes in engineering laboratories to deliver on-demand information and capture training needs at the time and location that is required.

Engineering courses often have big cohort sizes and often have either large practical classes or open access lab sessions. This makes it difficult to ensure that all students fully understand/remember the instructions given to them for a variety of different reasons. The instructional videos aim to give students another avenue to learn/review the instructions and use them as a recall tool should they require it. With this knowledge, the student is then able to safely carry out a task. This increases their confidence to perform the activity, thereby increasing their engagement with the task and their satisfaction when they complete the activities (Figure 1).

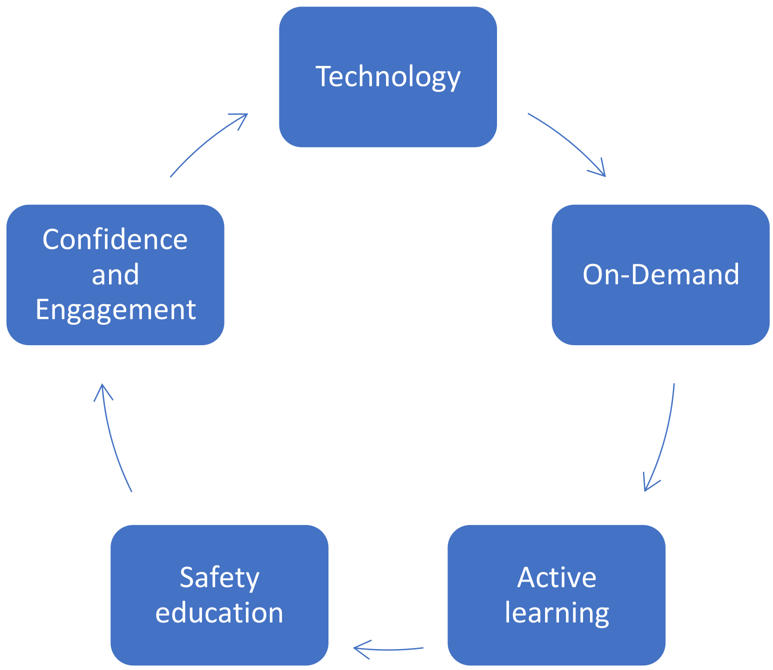



Figure 1: Project Motivation Factors.

## Implementation Methodology

The implementation plan was carried out in three phases: equipment scoping, storyboard planning and material creation. Videos and materials created were uploaded onto Vimeo (https://vimeo.com/), which is a free online video sharing site. QR codes linking to the relevant videos were then generated using an online QR code generator (https://www.qr-code-generator.com/).

Project implementation was carried out in the laboratories within the Department of Engineering. The project team consisted of academic staff, technical staff, apprentices and two second year Aerospace students. The rationale of engaging the technical staff was for practicality reasons, being familiar with the equipment and the safety measures required for use. Their knowledge of the equipment and lab activities contributed toward storyboard planning and the subsequent material creation. Students were consulted during the initial equipment scoping exercise to provide an insight to equipment that they have used in their studies and felt that would benefit from the QR code implementation.

## Equipment Scoping

There are approximately over 100 individual pieces of equipment and related activities in engineering that are in constant use by staff and students for teaching and research purposes. It was hence important to identify equipment and its associated activities that would benefit the most from this implementation. There are several factors that determined which equipment would be adopted for a pilot implementation, the inherent safety of the equipment, frequency of use by students, ease and effectiveness of training using a video medium. Two initial scoping meetings were held with students to discuss options and also to gather information on what students identify as essential in the video. Outcomes of these meetings have identified the following,

1. Clear and unobstructed view of the demonstration, with emphasis on safety or how to achieve a safe state when performing key tasks within the activity.
2. Narration or voice over to help them understand what is going on.
3. Short video length to aid attention retention and cognitive loading.

Three common, first-year activities have been identified by the students for the pilot implementation, soldering, balsa wood manufacturing techniques using hand tools and laser cutting. These activities form the most basic of skills required for the majority of engineering students over the course of their studies.

## Storyboard Planning

Storyboards are used to map out the entire video, frame by frame, before the start of filming. Storyboarding is an efficient and effective project planning tool to help identify and illustrate the various steps needed to complete a given project in a sequential manner (Barakat, 1989). Storyboards provides a structure link between the content authors and video creators before production process ensuring that key messages do not get lost in translation and errors are eliminated before production starts (Okur et al, 2010). Storyboarding is the focal point for planning and starts with determining the learning outcomes for each activity, the key skills demonstrated to students and the relevant control measures to ensure the activity can be performed safely (see Table 1). Length of videos was an important consideration and storyboarding allows us to determine the time required for each scene.

Table 1: Example of activity planning.

| Activity | Learning Outcome | Demonstratable skill | Safety Measures Demonstrated |
|---|---|---|---|
| Soldering | Safe soldering practice and use of extraction | • Using a soldering iron<br>• Soldering with extraction | • Extraction use and check<br>• Awareness of hot soldering tip. |

## Material Creation

The aim is to equip students with knowledge and training to safely perform their lab activities using bespoke instructional videos. These user centred videos focussed on safe working principles were recorded in engineering laboratories by technical staff for each of the activity. Narrations and captions for the videos were added post-production. QR codes were generated for the videos and the codes then placed on or in the vicinity of the equipment for ease of access (Figure 2).

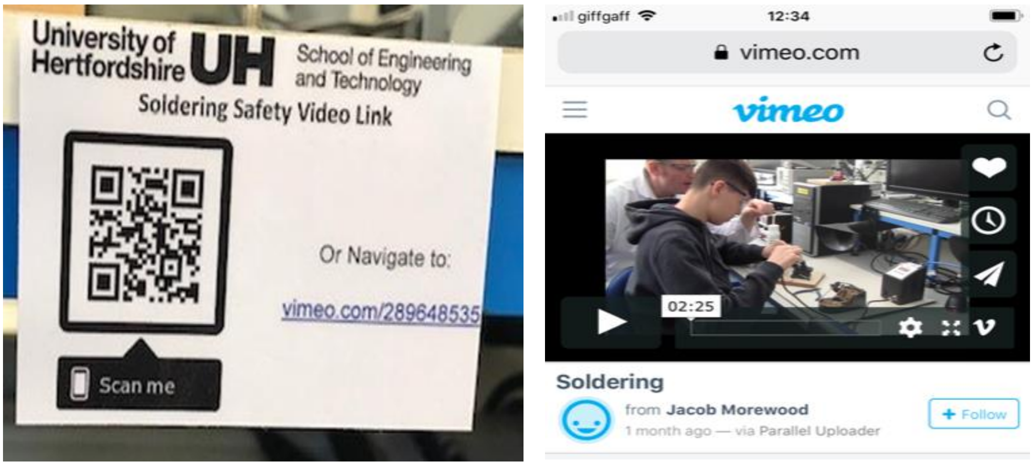
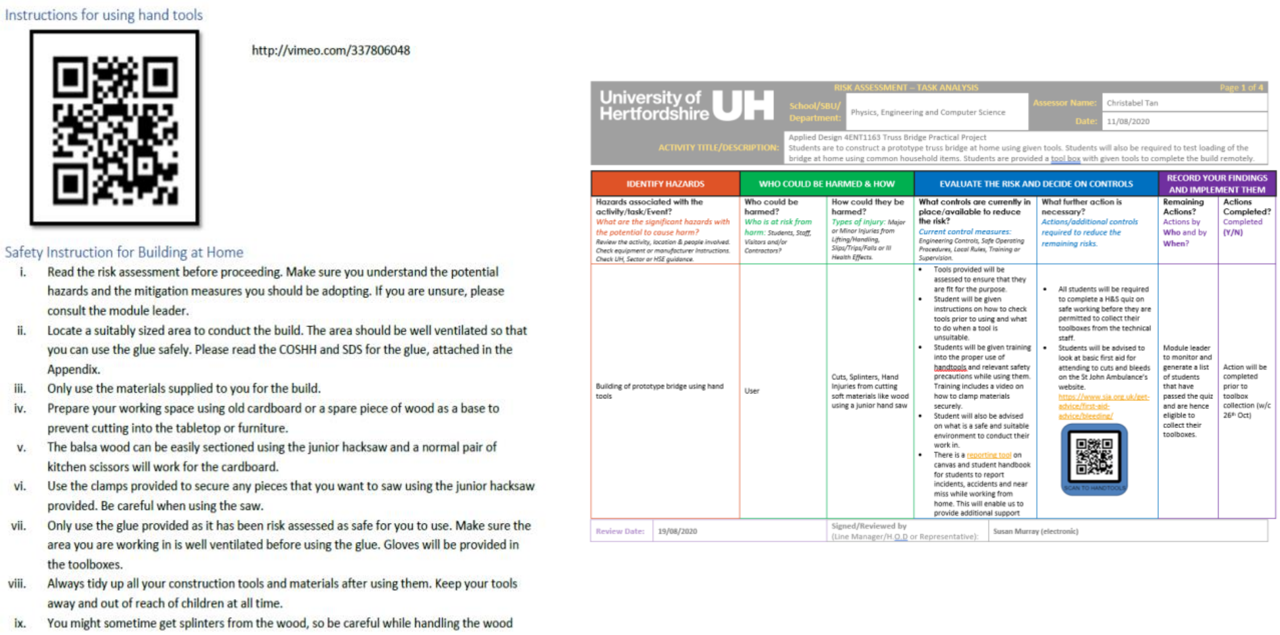



Figure 2: QR codes for soldering in electronics lab.

The QR codes will embed in them, links to bespoke instructional videos and/or training materials for the safe use of equipment and demonstrate procedures for specific activities that are deem hazardous to perform with prior specific training and/or instructions. These codes are located on the equipment itself or in a nearby location. It must also be recognised that not all students own a smartphone or want to download the free QR reader app, hence it is anticipated that all information will also be available on Canvas or in any relevant information provided to students. This academic year, due to the need to supply tools for students to complete practical work at home, QR codes have been included in the relevant risk assessments and project information handbook for students (Figures 3 and 4).



Instructions for using hand tools

http://vimeo.com/337806048

Safety Instruction for Building at Home

i. Read the risk assessment before proceeding. Make sure you understand the potential hazards and the mitigation measures you should be adopting. If you are unsure, please consult the module leader.
ii. Locate a suitably sized area to conduct the build. The area should be well ventilated so that you can use the glue safely. Please read the COSHH and SDS for the glue, attached in the Appendix.
iii. Only use the materials supplied to you for the build.
iv. Prepare your working space using old cardboard or a spare piece of wood as a base to prevent cutting into the tabletop or furniture.
v. The balsa wood can be easily sectioned using the junior hacksaw and a normal pair of kitchen scissors will work for the cardboard.
vi. Use the clamps provided to secure any pieces that you want to saw using the junior hacksaw provided. Be careful when using the saw.
vii. Only use the glue provided as it has been risk assessed as safe for you to use. Make sure the area you are working in is well ventilated before using the glue. Gloves will be provided in the toolboxes.
viii. Always tidy up all your construction tools and materials after using them. Keep your tools away and out of reach of children at all time.
ix. You might sometime get splinters from the wood, so be careful while handling the wood

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| | | | |
|---|---|---|---|
| School/SBU/ Department: | Physics, Engineering and Computer Science | Assessor Name: | Christabel Tan |
| | | Date: | 11/08/2020 |
| ACTIVITY TITLE/DESCRIPTION: | Applied Design 4ENT1163 Truss Bridge Practical Project<br>Students are to construct a prototype truss bridge at home using given tools. Students will also be required to test loading of the bridge at home using common household items. Students are provided a tool box with given tools to complete the build remotely. | | |

| IDENTIFY HAZARDS | WHO COULD BE HARMED & HOW | | EVALUATE THE RISK AND DECIDE ON CONTROLS | | RECORD YOUR FINDINGS AND IMPLEMENT THEM | |
|---|---|---|---|---|---|---|
| Hazards associated with the activity/task/Event? *What are the significant hazards with the potential to cause harm?* *Review the activity, location & people involved. Check equipment or manufacturer Instructions. Check UH, Sector or HSE guidance.* | Who could be harmed? *Who is at risk from harm: Students, Staff, Visitors and/or Contractors?* | How could they be harmed? *Types of injury: Major or Minor Injuries from Lifting/Handling, Slips/Trips/Falls or Ill Health Effects.* | What controls are currently in place/available to reduce the risk? *Current control measures: Engineering Controls, Safe Operating Procedures, Local Rules, Training or Supervision.* | What further action is necessary? *Actions/additional controls required to reduce the remaining risks.* | Remaining Actions? Actions by Who and by When? | Actions Completed? Completed (Y/N) |
| Building of prototype bridge using hand tools | User | Cuts, Splinters, Hand Injuries from cutting soft materials like wood using a junior hand saw | • Tools provided will be assessed to ensure that they are fit for the purpose.<br>• Student will be given instructions on how to check tools prior to using and what to do when a tool is unsuitable.<br>• Students will be given training into the proper use of handtools and relevant safety precautions while using them. Training includes a video on how to clamp materials securely.<br>• Student will also be advised on what is a safe and suitable environment to conduct their work in.<br>• There is a reporting tool on canvas and student handbook for students to report incidents, accidents and near miss while working from home. This will enable us to provide additional support | • All students will be required to complete a H&S quiz on safe working before they are permitted to collect their toolboxes from the technical staff.<br>• Students will be advised to look at basic first aid for attending to cuts and bleeds on the St John Ambulance's website. https://www.sja.org.uk/get-advice/first-aid-advice/bleeding/<br>SCAN TO HANDTOOLS | Module leader to monitor and generate a list of students that have passed the quiz and are hence eligible to collect their toolboxes. | Action will be completed prior to toolbox collection (w/c 26th Oct) |

| | | | |
|---|---|---|---|
| Review Date: | 19/08/2020 | Signed/Reviewed by (Line Manager/H.O.D or Representative): | Susan Murray (electronic) |

Figure 3: QR code in module documents.




Figure 4: Examples of QR codes developed in this phase that are currently available to students.

## The Future of QR in Engineering Labs

Mass training sessions, whereby all students are trained regardless, are ineffective, resource and logistical demanding and do not cater to the specific needs of individual students. The QR codes hence act as bespoke training tools for the students that require the specific training. A well-prepared video or instruction helps avoid the issue of variability in quality which may arise when different staff members demonstrate techniques to different students. Time is also saved if students watch the videos as advance preparation for the sessions hence enabling them to have a more productive time during the session.

The potential of QR codes in engineering laboratories is endless, placed out-side of laboratories, QR codes could indicate lab information and facilities without having to enter, what class is taking place and what the class is currently working on to ensure that students are in the right place at the right time. Similarly, codes placed outside of research labs could link to sites describing the research conducted, providing contact information for the researchers and linking to further resources on research interests, such as past publications, to promote research within the body of students.

Impact from this will be from the enhanced engagement due to increased confidence with the practical tasks due to clearer instruction and training. This will result in a better and more efficient use of staff in these sessions as they can focus on giving assistance towards the task rather than teach students on how to operate machinery. After initial training, students can tend choose to access the materials again for refresher, as and when necessary or use it as a live demonstrator during laboratory sessions to help them get through areas that they are experiencing difficulties with.

## Discussion and Conclusion

This paper has outlined how the implementation of QR codes containing safety training was designed and roll-out to students in Engineering. A total of three videos were identified and recorded for students. Although the focus of this project is primarily health and safety, the use of QR codes can be easily extended to also include other relevant information that can complement the learning experience, for example, linking reading list for enhance background reading or manufacturers information for further reference. The flexibility and ease of implementing this technology also means that it could be easily extended to other schools and for non-academic purposes, like information on artwork across the university.

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